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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,397,431**, on August 9, 2002, by **BLUESPACE TECHNOLOGIES INC.**, assignee of Andrew Lohbihler, for "Method and Apparatus for a Wireless Position Sensing Interface Device Employing Spread Spectrum Technology of One or More Radio Transmitting Devices".

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Method and Apparatus For a Wireless Position Sensing Interface Device Employing Spread Spectrum Technology of One or More Radio Transmitting Devices

Abstract of the Disclosure

A wireless transmitter and array receiver apparatus for receiving input from one or more wireless radio transmitting devices employs a spread spectrum signaling arrangement to transmit signals from the devices for identification and location determination. Spread spectrum techniques may include DSSS, FHSS, THSS, chirp, or combinations thereof. Passive transmitter devices operate in the propagation medium and radiate EM energy to signal receivers, where radiated signal-strength and carrier-phase difference measurement techniques are used to determine location, and spread spectrum encoding is used to identify the devices. Transmitter devices may generate one or a plurality of data signals that are spread spectrum encoded, to be decoded by said receiver. One or a plurality of transmitter signals are received, located, and identified by the SS methods and use ASK and FSK data modulation schemes to reduce the effects of signal multi-path and occlusion.

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FIELD OF INVENTION

This invention relates to a wireless position sensing computer input device that is responsive to a electro-magnetic transmitting device that is physically moved in three dimensional space. The receiver is passive and can receive signals from multiple transmitting devices that use unique DSSS pseudo-noise (PN) modulating codes. A single receiver can simultaneous receive and position multiple transmitters allowing complex position and angle orientation measurement.

BACKGROUND OF INVENTION

Computer systems configured with human interface devices have been common for nearly two decades and are popular in a wide variety of business and educational applications. The most common interface devices comprise a number of processing devices (commonly as the mouse device) and a computer that are coupled together by a hard-wired connection. Since about 1990, however, wireless interface devices have become more common in the marketplace. Although the concept behind wireless interfaces had been described a decade earlier, interest in wireless interfaces was limited until the release of the 2.4 GHz unlicensed band for industrial, scientific and medical (ISM) applications. Wireless interface products most often employ either direct sequence spread spectrum (DSSS) or frequency hopping spread spectrum (FHSS) techniques to communicate between a handheld device and a local receiver that interfaces with a computer and display monitor.

There are many types of non-wireless interface devices including touch sensitive computer input devices currently used for the purpose of digitizing touch on or in conjunction with computer displays. Such devices measure the position of a transmitter, stylus or finger touch on the sensor surface (see Stein et al. patent 5,365,461). The position is used to generate coordinates for the purpose of interacting with the computer, for example in pointing to icons on the display, picking menu items, editing computer generated images, and feedback for input of hand-drawn characters and graphics.

Such devices that sense wireless signals, corded devices, or human touch may sense using any number of technologies, including capacitive sensing, resistive sensing using a conductive overlay sheet, infrared sensing, acoustic wave sensing, and piezoelectric force sensing. Digitizers which use corded or tethered hand held styli such as pens or pucks typically use electromagnetic sensing, electrostatic sensing, resistive sensing, or sonic pulse sensing.

Devices responsive to wireless or corded transmitters are typically used for cursor control application, for example pointing to display icons and picking menu items. Devices that are responsive to styli (usually a wireless or corded pen) are used to create or trace drawings, blueprints, or original art. These devices are also used for character or handwriting recognition. It is desirable that the wireless or corded device have a pen and paper feel so that their use is intuitive to most users. It is therefore desirable that the transmitting device reproduce the trace of the pen below the stylus by some visual means so that the user has visual feedback.

Wireless devices generally don't require to have an intuitive pen-and-paper feel but require that the user see the cursor appear on the interface screen under the touch of the pen before the writing surface is touched. For this reason wireless styli are limited to no more than 5 centimetres of wireless operation off the stylus writing surface (example: the Wacom pen).

Some wireless devices operate at longer ranges (1 to 3 metres) from the computer screen and are based on infra-red and acoustic media to transmit signals that are used to locate the transmitter in 3D space. The signals are received by a base receiver that triangulates the position of the handheld device based on time-delays. These devices are suitable for handicapped users, and for users who require an interface over a wider volume of space such as for game interfaces. These technologies have limited range of operation and commonly require that a power cable be tethered to the hand-held device to provide power and allow switch signals between the handheld device and a base receiver. Accordingly, these devices are rather awkward to use as they are not fully wireless.

Lately the emergence of 3D graphical games has necessitated requirement for 3D wireless devices allowing users to interface with games with built-in 3D features. There is also a need to get faster rate data for positioning to allow users to have a more natural interaction with the computer, for smoother positioning that are delay free. Also needed is a higher resolution positioning for increasingly sophisticated games and interfaces with high resolution computer screens. There is an increasing need for devices that are truly wireless and allow multiple users to interface with the same interface screen, and with a variety of controller functions.

The prior art does cover many devices and methods that offer a radio-based wireless interface with a computer but there are no devices that interface with a computer that allow multiple device to operate simultaneously. Limitations of devices that multiplex between their operation of XY and XYZ positioning include a slow position pointing rate. Also, many methods mentioned in prior-art do not operate effectively in short range (also call the “near-field”) for which their accurate operation is not possible.

What follows is a background for the invention in the following sections, to discuss prior-art for multiple device detection and methods of accurate positioning models.

Spread Spectrum Signals

In this invention, a variety of SS signals with different structures can be used. These signals include Direct Sequence Spread Spectrum (DSSS) signals, Frequency Hopping Spread Spectrum (FHSS) signals, Time Hopping Spread Spectrum (THSS) signals, Linear Frequency Sweeping (Chirp) signals, Hybrid signals, and the like.

As noted, wireless products frequently employ some type of spread spectrum technique, such as direct sequence spread spectrum (DSSS) or frequency hopping spread spectrum (FHSS), to communicate between the transmitter and receiver (single or two-way). A distinguishing feature of the spread spectrum technique is that the modulated output signals occupy a much greater transmission bandwidth than the baseband information bandwidth requires. The spreading is achieved by encoding each data bit in the baseband information using a codeword, or symbol, that has a much higher frequency than the baseband information bit rate. The resultant "spreading" of the signal across a wider frequency bandwidth results in comparatively lower power spectral density, so that other communication systems are less likely to suffer interference from the device that transmits the spread spectrum signal. It also makes the spread signal harder to detect and less susceptible to interference (i.e., harder to jam).

Both DSSS and FHSS techniques employ a pseudo-random (PN) codeword known to the transmitter and to the receiver to spread the data and to make it more difficult to detect by receivers lacking the codeword. The codeword consists of a sequence of "chips" having values of -1 or +1 (polar) or 0 and 1 (non-polar) that are multiplied by (or Exclusive-OR’ed with) the information bits to be transmitted. Accordingly, a logic "0" information bit may be encoded as a non-inverted codeword sequence, and a logic "1" information bit may be encoded as an inverted codeword sequence. Alternatively, a logic "0" information bit may be encoded as a first predetermined codeword sequence and a logic "1" information bit may be encoded as a second predetermined codeword sequence. There are numerous well known codes, including M-sequences, Walsh codes, Barker codes, Gold codes and Kasami codes.

Multi-path Reduction

Multi-path propagation is a phenomenon that occurs, for example, if there are reflectors, obstacles, and boundaries, etc., in the propagation medium. A receiver in the wave field will receive not only a signal from a signal source through a direct propagating path, but it will also receive signals (called multi-path signals) reflected from these objects. Multi-path signals are always delayed as compared to direct-path signals. In fact, multi-path signals can severely degrade the system's performance if they are not separated from the direct-path signal.
In a SS system, Δt, the width of the main lobe of correlation function after de-spreading, can be written as:

$$\Delta t = \frac{1}{BW_{Code}} \qquad (1)$$

where BW_{code} is the bandwidth of the SS code used for despreading. Δt can be regared as the ability of a SS system to resolve multi-path signals from their direct-path signal after despreading.
The following is an example showing that the multi-path problem can be eliminated by the present invention. Given: an radio signal is propagating through the air at an approximate speed of sound $Vs = 330m/s$ and $BW_{code} = 1MHz$, then Δd, the minimum distance between a direct-path signal and the multi-path signals that a SS system is able to resolve, becomes:

$$\Delta d = \Delta t * V_S = \frac{V_S}{BW_{Code}} = \frac{330}{1,000,000} = 0.33mm \qquad (1.1)$$

That is to say, any multi-path signal that is 0.33mm away from the direct-path signal can be removed. This is very difficult to achieve in narrowband systems.

Other methods of multi-path rejection include:

- Adaptive equalization with a training signal
- Blind-equalization (where no training code is required)
- Antenna array diversity
- Frequency diversity
- Antenna polarization diversity

The adaptive and blind equalization methods improve the signal corrupting effects of signal multi-path by recovering the signal strength during a signal fade-out. An equalizer in a receiver compensates for the average range of expected channel amplitude and delay characteristics. Equalizers must be adaptive since the channel is generally unknown and time varying.

Antenna diversity by contrast exploits the random nature of radio propagation (or at least highly uncorrelated) signal paths. Diversity design implementations are done at the receiver and are unknown by the transmitter. The strategy for diversity occurs by recognizing that a receiver element is experiencing a deep fade-out while other receiver elements receive strong signals. Consequently the faded signal phase calculation is excluded from the location calculation.

Frequency diversity is based on simultaneously transmitting on more than one carrier frequency such that while one (or more) channels will fade, others will not allowing some coherent signaling to occur. FSK modulation of a PN code in direct sequence may be used but would require a large frequency spread to make the diversity workable. For instance if the frequency spread was small, both channels can experience the same degree of multi-path fading

Polarization diversity is based on the assumption that the transmitting antenna polarization is not known and that received signals to multiple antenna elements are uncorrelated. Cross polarized antennas have multiple spatial elements and reduce multi-path effects by reducing phase delay caused by receiving multiple signal reflections with different polarizations. This applies to signals that are blocked or obstructed at short range. For this invention a combination of the above techniques apply to make the multi-path effects minimal at short range and allow for better phase measurement.

SNR Improvement

It is well known that in a SS system, when the information bandwidth is evenly spread, the system Processing Gain (PG) can be expressed as:

$$PG(dB) = 10\log_{10}\left(\frac{BW_{Sig}}{BW_{Info}}\right) \qquad (2)$$

Having the PG, the SNR of the SS system can be improved to:

$$SNR_{SS} = PG + SNR_{Sig} \qquad (3)$$

where SNR_{SS} and SNR_{Sig} are the SNRs of a SS receiver and the transmitted signal respectively.

With improved SNR, SS systems in this invention can be designed in ways that are very different from narrow band receiver systems. The benefits of having improved SNR in a SS system include:

- SS systems can have higher noise immunity.
- Transmitter devices can be cost-effectively designed to have balanced noise immunity through spreading.
- Signals can be transmitted with less energy.
- Signals can propagate for longer distance.
- The power consumption of each transmitting device can be greatly reduced so that various power supply methods, which are impractical in some cases for narrowband devices, can be used.
- Passive transmitter devices can be widely introduced.
- Higher position location resolution can be easily achieved.

For example, for a SS system with $SNR_{Sig} = -10\text{dB}$ (signal energy is 10-times less than noise) and PG = 30dB (signal bandwidth is 1000-times wider than information bandwidth), its $SNR_{SS} = 20\text{dB}$. That is to say, with a properly designed PG, the SS system can pick up information from signals below noise. A narrowband system can not work on an environment that has negative SNR, unless some additional signal processing methods, e.g. signal averaging, are used.

Phased array receivers

Each DSSS radio receiver in a phased array receives a transmitter signal in the form of a DSSS code modulated carrier wave. Each receiver connects to a common LO (local Oscillator) that when mixed with the received radio wave, will down-convert the RF wave to an IF (Intermediate Frequency) wave. The frequency of the IF wave is determined by:

$$f_{IF} = f_{RF} - f_{LO} \qquad (4)$$

and is usually a frequency between 1 MHZ and 100 MHz. A suitable IF is chosen to minimize the phase-noise between the IF signals measured at all elements in the phased array. At this point it should be noted that the IF signals are "phase coherent" meaning that they have a common phase reference. The IF signals are then entered through an analog phase/amplitude detector. This is done by splitting the signals into their I (in-phase)

and Q (quadrature-phase) components such that the phase and amplitude signals are determined by:

$$\Phi(t) = \tan^{-1}(I/Q)\ , \qquad (5)$$

$$A(t) = \sqrt{I^2 + Q^2}\ , \qquad (6)$$

The phase and amplitude signals are still code modulated signals at this stage and are sampled with a fast ADC circuit (Analog-to-digital converter) and hence sent to a DSP circuit for further processing. A CDMA processor will use a code matching filter to determine which code will correlate with the input signal producing a correlation peak output, thereby determining which transmitter is transmitting at that time. The DSP uses a fast multiplexer to correlate multiple codes using a fast parallel multiplexer architecture. This can be implemented with high-speed parallel DSP and FPGA designs.

Location tracking

The Location Tracking model in this invention uses the radiated signal strength (RSS) and the relatively measured radio carrier phase-delay (CPD) to position the radio transmitting device(s). The phase delay is measured between signals received at a minimum of two receivers. This method will be referred to as the CPD model.

The CPD model used in this invention is based on radio signals propagating through 3D space. That is, when a wave field is confined to propagating through 3D space, such as the free space in which an EM signal propagates, the associated RSS is then modeled to be linearly proportional to the inverse square of R, which is:

$$RSS \propto 1/R^2 \qquad (7)$$

where R is the distance between a radio transmitting device and a receiver element. However, in the CPD model the relative phase-delay between two receivers is related to the relative distance that a radio signal transmitter is away from said receivers as;

$$\Delta x = \Delta\Phi\lambda/2\pi \qquad (8)$$

where λ is the wavelength of the radio carrier signal. Together with RSS and phase-delay measurements the receiver array may determine the XYZ location of a transmitting device. Using these principles, when more than one receiver is used, a plurality of radio transmitting devices may then be tracked by receiving and calculating the relative RSS and

phase-delays as CDMA codes signals. To obtain the required RSS and CPD estimation of a radio transmitting device, in this invention the following steps are performed:

1. Use the DSSS code (e.g., CDMA code) of input device to matched-filter the received and digitized RSS or phase-delay signals;
2. Obtain the peak of the matched-filtering output function, namely the RSS, to identify the device. If needed, use an interpolation procedure to find the peak at a higher resolution;
3. Use an averaging procedure to measure the average amplitude of the match-filter peak as a measure of RSS and phase-delays for a specific device code. An example is to sum the area of the correlation triangle as a weighted average;
4. Use the result from step 3 as the RSS and phase-delay estimation of this device.

Calibration models are established in this invention by taking several XYZ calibration points relative to the receiver array and converting them to RSS and phase-delay measurements. One way of establishing an experimental model is to set up a number of calibration points on a fixed plane in 3D space with constant Z, and take phase-delay and/or RSS measurements at these points. A matrix of experimental positioning data can then be established, and XYZ location resolution can be obtained and/or improved by interpolation using this data.

Device Communication

Communication models in this invention are similar to common DSSS communication systems known in the prior art. To perform communication procedures, after despreading, a bit decision is made based on the sign of the despreading correlation peak output for a particular radio transmitting device. If a radio transmitting device utilizes a switch to convey information (such as a wireless mouse using a "right-click") then the device will encode a data bit using "bit-inversion-modulation". That is, CDMA code will be inverted for one "bit-period". If more than one data event is conveyed by the radio transmitting device then multiple CDMA codes can be assigned for transmitting additional data information.

Power Supply for the Transmitting Device

In this invention, two different types of methods to supply power for the active radio transmitting devices have been developed, which include: 1) using a chemical battery; and 2) using an EM powering field in free space with a loop antenna and powering circuit in the transmitting device. It must be noted that, due to the fact that in this invention DSSS signals are used, an active radio transmitting device requires much less power than an

active device transmitting a narrow band carrier wave. This enables the above power supply methods to be more practical.

XY Display

A key performance parameter of any interface device, particularly to position high speed motion to a computer and display monitor, and the like, is the XY or XYZ coordinate data rate and the speed of data transferred from transmitter to receiver device. Wireless interface devices are no exception. It is therefore important to maximize the rate at which XY data is calculated and to also maximize the transfer of high-speed communication data at the same time.

Accordingly, there is a need in the art for systems and methods that increase the rate at which data may be transferred in a communication system using spread spectrum techniques to communicate data between a transmitter and receiver. The need for a transmitter device to have a data link varies significantly in data rate. Examples are from mouse clicks to a telemetry data channel. There is a still further need for systems and methods that increase the rate at which XYZ data may be calculated for multiple transmitters in a wireless interface device using spread spectrum techniques.

Prior Art

The concept of phased-array antenna signal processing for locating radio transmitters is and is extensively covered as prior art. The methods are several variations generally for the tracking of aircraft using active and passive radar and processing methods for characteristics about multiple objects that reflect radar signals. Generally, these methods involve 2-way signal paths which involves a radio pulse reflecting from an object (typically monopulse radar) or a transponded signal from an active transponder circuit. The art of determining the location of single emitters is covered in patent 6,147,646 requiring that each emitter have their angles-of-arrival (AOA's) determined and put into bins using a multiplexed processing approach.

Methods for determining the location of reflected or transponded radio emissions using phase differencing is covered in patents (4,788,548 4,977,365 5,285,209 5,343,212 5,477,230 5,497,461) for phased array radar applications. Generally these methods output the angle-of-arrival (AOA) of a signal and present the data to a display screen. These methods invariably use a linear one or two dimensional antenna array but do not involve signal spreading with CDMA codes, or the like.

Methods of range estimation are covered in past patents (4,788,548 5,510,795 5,745,437 5,999,131 6,177,907 6,288,776). These methods are either based in phase differencing

using range changes in curvature, phase differencing based on a two-way signal reflection, phase angle ambiguity calculation (common in synthetic aperture radar (SAR) methods), and range ambiguity estimation based on phase difference using signals with multiple frequencies. These range estimation techniques involve one or two-way signal paths involving signal reflections, transponded signals, and stationary or moving emitters.

Patent 6,198,436 discusses a method for receiving and separating signals from N-channels in a narrow-band communication system. Although this method is based on a coherent array of phased-array receivers, the signals are processed as a multiplexed processor arrangement to separate the signals of several channels.

The use of CDMA methods is extensively covered in prior patents for cellular phone technology and networks, wireless LANs, as well as for locating cell phones, and GPS systems and receivers. Specific patents (5,999,131 6,081,229 6,249,680) cover the use of CDMA for locating radio transmitters. These methods distinctly cover location estimation based on time-delay-of-arrival (TDOA) for which ranges are estimated based on time delays. Techniques of this kind are impractical at close range because time delays are too short to be measured reliably and accurately. The benefits of methods for AOA estimation to locate transmitters in short range is not cited in CDMA patents and literature, and especially for multiple CDMA emitters.

Other patents (5,510,800 5,589,838) cover the use of Ultra-Wide Band (UWB) technology for radio location in the short range. These methods are practical for short range locating of radio transmitters and can adopt CDMA techniques to locate multiple transmitters, however, they depend on the emergence and wide acceptance of UWB technology standards.

SUMMARY OF INVENTION

It is therefore an object of this invention to provide a wireless position sensing input device, which simultaneously positions multiple transmitting devices in 3 dimensional space.

It is a further object of this invention to provide such an input device which simultaneously positions multiple transmitting devices on a 2 dimensional plane at a fixed distance from the said input device.

It is a further object of this invention to provide such a device which allows the display of the transmitter trace on the input device.

It is a further object of this invention to provide such a device in which the transmitter sensing is through a virtually transparent medium.

It is a further object of this invention to provide such a device with relatively simple and inexpensive circuitry.

It is a further object of this invention to provide such a device that has fast response.

It is a further object of this invention to provide such an input device that can digitize over 1000 transmitter device points per second and per transmitter.

It is a further object of this invention that it provide a high accuracy of position sensing of less than 1 milli-metre for one or multiple transmitters.

It is a further object of this invention that the transmitting device provide a low data-rate information communication link between the transmitter and receiving input device allowing the input of user data to an interface computer. Examples of this data link are to allow users to convey select button presses, mouse clicks, digital data signals.

It is a further object of this invention that the receiving array process individual array receivers in parallel and allow transmitting devices to be simultaneously detected and positioned in 3-dimensional space for presentation on an XY or XYZ display.

It is a further object of this invention that the receiving array process individual array receivers in parallel and allow multiple positioned transmitters to be interacting for several purposes such as for a 2D or 3D mouse interface, tilt-joystick, point-and-shoot device, 6DOF device, and gesture interface devices.

Brief Description of the Drawings

Other objects, features and advantages will occur to those skilled in the art from the following description of a preferred embodiment and the accompanying drawings, in which:

Figure 1A depicts radio transmitting devices being detected and located in 3D space and presented to a 2-dimensional XY screen display.

Figure 1B depicts radio transmitting devices being detected and located in 3D space and presented to a 3-dimensional XYZ screen display.

Figure 2 depicts the multiple device detection system for locating multiple radio transmitting devices and extracting data signals from said transmitting devices.

Figure 3 depicts the detailed signal processing flowchart for each radio receiver channel to sense multiple radio transmitting devices.

Figures 4A, 4B, 4C depict the detailed design of the EM powering circuit, a self-powered radio transmitting device, and a battery powered radio transmitting device.

Figure 5 depicts the detailed system operation flowchart of the active radio transmitting device.

Figure 6 depicts the detailed system operation flowchart of the CDMA code detection system.

Figure 7 depicts the method of detecting multiple DSSS codes embedded in a common input signal.

Figure 8 is a detailed flowchart of the transposed-form matched-filter implementation for detecting multiple devices with CDMA codes.

Figure 9 depicts the method of using CDMA codes to communicate data bits from one or a plurality of radio transmitting devices.

Figures 10A and 10B are a top view and a perspective view of a 3-dimensional mouse controller in accordance with the present invention.

Figure 11 is a perspective view of a tilt joystick controller in accordance with the present invention.

Figure 12 is a perspective view of a point-and-shoot aiming controller in accordance with the present invention.

Figure 13 is a perspective view of a 6DOF controller in accordance with the present invention.

Figure 14 is a perspective view of a gesture interface controller glove in accordance with the present invention.

DESCRIPTION OF PREFERRED EMBODIMENT

This invention involves a plurality of electro-magnetic signal transmitting devices **1** positioned no more than a short range of R wavelengths from the electromagnetic receiver unit **2**, as shown in Figure 1A. The receiver unit **2** includes an array of electromagnetic receivers arranged in a flat plane or in a 3-dimensional configuration (although many shapes are possible). The receiver elements **3** are small and compact and require to be arranged such that their antennae are no more than a distance of half a wavelength apart from each other. The receivers each include an antenna **4** that receives the electro-magnetic field from one or a plurality of radio transmitter devices. The antenna **4** for the receiver units **3** are required to be compact and of the microstrip type to minimize polarization effects that cause positioning errors. The antenna **4** is also required to be a minimum distance from the receiver element circuitry to maximize antenna efficiency and minimize cross-coupling losses between element antennas.

An embodiment in this invention is determining the position of one or a plurality of free-moving radio transmitting devices in 3-dimensional space (also referred in this invention as XYZ space) and is shown in Figures 1A and 1B. A plurality of time varying electromagnetic transmission sources **1** transmit signals **5** to the receiver element array **2** of which each array element **3** receives a duplicate signal from transmitter. When a radio transmitting device **1** moves in XYZ space the relative phase difference of the received signal is linearly shifted between each of the array element receivers in proportion to the time difference of the received signal to each element **3**. The signal strength of said devices **2** also simultaneously changes in proportion to distance between each receiver array element **3**. The phase difference and signal strength difference will vary for any pair of receiver array elements **3** that are simultaneously sampled. The degree of phase difference and signal strength difference varies according to a "near-field" or short-range radio mathematical model.

An embodiment of this invention is that the radio receiver array unit **2** can be arranged in different element geometric patterns to provide the optimum ability to discern the phase and signal strength difference between any pair of receiver elements **3**. For two-dimensional position determination (or XY position display shown in Figure 1A) the array elements were arranged as a group of four receiver elements **3**, such as arranged with all receivers at the corners of a rectangle with four receiver elements overall. For three-dimensional XYZ position determination (or XYZ position display shown in Figure 1B) the array elements **3** were arranged with any group of three receiver elements arranged linearly. For example the receiver elements **3** at the corners of a square and with four elements between them (eight receiver elements overall) has 4 groups of three elements each to determine the Z coordinate.

As one embodiment in this invention a radio receiver **2** for multiple active radio transmitting devices with CDMA DSSS signal structure is discussed. The fundamental hardware function blocks of an active radio transmitting device **1** are illustrated in Figures 2 and 3. This embodiment generally comprises a method and apparatus for tracking one or more active radio transmitting devices **1** to a radio receiver array **2** using the spread spectrum signal structure incorporating CDMA DSSS codes. Such radio transmitting devices **1** may include a combination of devices such as a 2D or 3D wireless mouse, a tilt joystick, point-and-shoot device, 6DOF controller, and a gesture interface controller, or its equivalent.

The apparatus of the invention includes at least one, and preferably a plurality of active radio transmitting devices **1**, applying radio transmitting input to a radio receiver array **2**, and stimulating a plurality of radio receiver elements **3**, as shown in Figure 3. In terms of hardware implementation of the active radio transmitting devices **1**, they all have generally the same electrical circuitry, with only a small modification according to their specific functionality. Signals received by the receiver array **2** are also received independently by each receiver element **3** and processed by a multi-channel signal processor **6** such that the XYZ location of each radio transmitting device **1** is determined by a locator 7. Location and identification data is sent to an interfacing computer **8** for presentation to an XY display unit **9** or an XYZ display unit **10**. The display image (i.e. as a cursor for example) is shown in the display viewing area **11**.

In Figures 2 and 3, the receiver array area **2** consists of a plurality of radio receiver elements **3** that pick up signals **5** that vary in voltage while oscillating at a radiating frequency (RF). Each RF receiver element antenna **4** that picks up the transmitter signals minimizes any cross-coupling of the antenna field with any other receiver array element **3**. A low-noise amplifier (LNA) **18** boosts the signals and image rejection filter (or band-pass filter) **19** separates the wanted narrowband carrier signal from external interference. A mixer circuit **21** mixes the RF input signal with a Local Oscillator **20** signal to generate a downconverted intermediate frequency (IF) signal. An IF amplifier **22** boosts the IF signal to a necessary voltage for the I/Q demodulator **23** splits the IF signal into an in-phase "I" signal and a quadrature-phase "Q" signal. An analog-to-digital converter (ADC) **24** converts the I and Q signals to digital form and a matched-filter unit **12** collects the RSS and phase information **25** for all functioning devices, and a detector **13** determines which devices are present. The detector **13** uses stored PN codes **15** to detect with device codes and store the device detection data **27**. A transmitter detector **13**, and data extractor **14** removes modulated data from the CDMA signal of each radio transmitting device **1**. A device locator **7** removes nonlinear RSS variations and fluctuations caused by changes in the radio transmitting environment to the radio receiver array **2**. A frequency measurement unit **26** determines the frequency of the IF signal to each channel (necessary for the

location calculation). The device locator **7** determines the XYZ location of each active radio transmitting device based on frequency data **26**, RSS and phase data **25**. XYZ location 17, identity **27**, and device data **16** are assembled into packets for interface with a computer **13**.

In Figure 4A, there is a EM field generator unit **28** to provide an EM field tuned to the same frequency as the radio transmitting device power coil **29**. EM energy is radiated from the EM field coil **29** and induced by the radio transmitter power coil **31**, and regulated by the device power circuit **32**. The radio transmitting device power circuit supplies sufficient voltage to the RF signal modulator circuit **33**. Each radio transmitting device **1** also includes a CDMA PN Code **34** supplied to a read-only-memory (ROM) **35a** or a linear-feedback shift register (LFSR) generator **35b** to generate unique CDMA codes. A voltage controlled oscillator (VCO) **37** provides the RF wave when modulated with the PN code produces an RF modulated waveform. A switch **36** will send a single data bit to the modulator **33** to modulate the PN code to communicate switch events. The RF modulator **33** will periodically and/or continuously generate communication signals modulated by the CDMA PN code of this device. These CDMA signals are provided to a pulse shaping circuit **38** and then to an antenna to transmit the coded signal **5**. The EM powered radio transmitting device will operate only within range of the EM powering field area **30** (see Figures 4A and 4B).

In addition to the active radio transmitting devices disclosed above, there are also embodiments to perform the radio transmitting device powering functions away from the receiver array **2**. Figure 4A shows a EM power coil 16a which is used to create a strong EM field **17a** around the receiver array area **2** allowing radio transmitting devices on or near the powering surface area **30** to be wirelessly powered by an induction coil **31** as shown in Figure 4B. In other embodiments the power coil **29** can be separate and away from the receiver array **2** still allowing transmitting devices **1** to receive the EM field **30a**. The induction coil **31** will be in resonance or near-resonance with the EM power field using a resonance capacitor **31a** to optimize powering. Another embodiment is to separately include self-contained power source **40** (such as a chemical battery) as shown in Figure 4C.

There are various ways of implementing the RF modulator **33** in this invention in a cost-effective way for the radio transmitting device designs illustrated in Figures 4B, 4C. The most common approaches being to use a digital ROM **35a** to read a fixed CDMA code, or to use an LFSR **35b** to generate the CDMA code using fixed circuit logic or programmable firmware. The ROM **35a** or LFSR **35b** will first generate the CDMA signature in square wave, and then send this signal to the RF modulator **33** along with a

VCO **37** signal. The antenna **39** can be various types but must be a miniature microstrip, loop, wire, whip, feed-through dipole, or the like.

The RF modulator **33** initiates its own operation by getting a clock signal from an internal clock source, to request the next CDMA chip" or code bit from the ROM **35a** or LFSR **35b**. When a sequence of this data is clocked out, it forms a CDMA code sequence signal that is modulated and sent to the antenna. Note that the CDMA code can be either successively repeated after the code-end is reached or is repeated after a delay period.

The active radio transmitting device **1** or a combination of said devices may take any of several forms that have been disclosed in the prior art. As shown in Figures 10A-10B, a radio transmitting 3-dimensional mouse **41** may have a single radio transmitting point **42** to perform its function. The device may move in 3-dimensional space and will always provide a positioning cursor in the view area of the receiver array **2**. This positioning cursor **11a** will indicate information relevant to the mouse position in 3-dimensional space and providing said information to an XY or XYZ display as shown in Figures 1A and 1B. The contact point will radio transmit to the receiver array surface **2** with a RF modulated CDMA PN code signal **5** from antenna **39** located at transmitter point **42**. The 3D mouse **41** is equipped with the right button **44** and the left button **43**, are designed as moveable buttons to yield the clicking status.

With regard to Figure 11, a tilt-joystick controller 45 includes at least two radio transmitting devices **46,47** within itself such that the devices are placed near or at the extreme ends of the tilt device. Each device **46,47** will transmit a different CDMA code such that each device is located independently and simultaneously by the CDMA detector **7**. The locator will then compute a relative tilt between the devices and as a forward tilt angle and a side tilt angle. The position of the tilt-joystick is also determined as the average position **48** of the said radio transmitting devices **46,47**. The joystick may operate in either tilt-joystick mode or mouse mode, in which event data is communicated from a left switch button **49** to the left transmitter **47**, and the right switch button **48** to the right transmitter **46**, where modulated codes are generated.

With regard to Figure 12, a point-and-shoot controller **50** includes at least two radio transmitting devices within itself such that the devices are placed along a linear path. Each device **51,52** will transmit a different CDMA code such that each device is located independently and simultaneously by the CDMA detector **7**. The locator will then compute a linear direction determined by an inner and an outer device locations, and the intersection point of the direction line with the viewing plane is presented on an XY display screen **11**. This allows the user to point or aim at a displayed object shown on the display screen **11**. One or more switch buttons may be pressed, in which event data is

communicated from switch buttons **53** and **54** to the transmitters **51** and **52** irrespectively, where modulated codes are generated.

As shown in Figure 13, a 6DOF **55** may include at least three radio transmitting devices within itself such that the devices are placed near or at the vertexes of a triangular plane. Each device **56,57,58** will transmit a different CDMA code such that each device is located independently and simultaneously by the CDMA detector **7**. The locator will then compute relative angles between the devices based on their XYZ locations. The orientation angles computed will be one or more of Roll, Pitch, and Yawing angles of a model aircraft, or a similar object. The position of the 6DOF object is also determined as the average position **61** of the said radio transmitting devices. Switch buttons may exist on the object **59,60** which send event data to one or more transmitter devices **56,57,58** where modulated codes are generated.

As shown in Figure 14, a gesture interface **63** may include at least one radio transmitting devices **65** within itself such that the devices are placed on the hand or glove **62** to indicate the relative position of fingers to a reference point **64** on the glove **62**. Each device will transmit a different CDMA code such that each device is located independently and simultaneously by the CDMA detector **7**. The gesture interface locator will then compute relative changes in XYZ position between the devices. The changes of the finger-tip transmitter **65** locations relative to a reference point **64** will be compared with stored position patterns and be recognized as specific hand gestures.

In the preferred embodiment the radio receiver array **2** is configured in a familiar rectangular format, though a wide variety of shapes are possible. At each receiver element vertex of the surface **2** there is disposed an antenna **4** to receive signals from the active radio transmitting devices **1**. The antennas are connected to radio receiving element circuits as part of the analog processor **6** and digital CDMA detector **7**. The analog portion does the typical signal reception function of a communication channel, such as power amplification, filtering, ADC, etc. After signals from radio transmitting devices are sampled and digitized, the CDMA signal processing unit **7** is used to do the necessary signal processing procedures, such as code synchronization, matched-filtering, RSS and CPA determination **25**. These results are then passed to a Device Detector **13**, Data signal extractor **14**, and Device Locator **7** to acquire data for the desired system operation, such as device identification, tracking and communication, etc. Finally, this data are transferred to a master CPU controller **8**. This data may then be used in a computer system, or any electronic device that may employ a wireless interface.

In this embodiment that there is always a one-way communication between the active radio transmitting devices **1** and the radio receiving array **2**. Typical CDMA systems use a return link for synchronization purposes, however it is very possible to manage CDMA

devices asynchronously to perform system functions well. This will greatly save the cost of the system implementation.

In this embodiment outlined in Figure 3, each signal receiver element **3** has a separate independent antenna 4, a separate A/D converter (ADC) **24**, and a separate code multiplexed matched-filter **25** which operates in parallel with each other receiver element **3**. The signal from each receiver element **3** is a mixture of CDMA signatures from all the active devices operating in the receiver array. The signals of each channel are fed to a signal low-noise amplifier **18** and thence to a band-pass filter **19** to remove unnecessary RF noise and interference. The signals of each channel are mixed with the signal of a common Local Oscillator (LO) **20** and the output IF signal is amplified **22** and I/Q demodulated **23**. The I/Q demodulated CDMA signal is fed to an ADC **24** for each I and Q signal to be converted into digital format and stored in a data register inside the CDMA detector **25**, ready to be processed by a matched-filter.

Each radio receiver element 3 receives a copy of a transmitter signal in the form of a DSSS code modulated carrier wave. Each receiver connects to a common LO (local Oscillator) that when mixed with the received radio wave, will down-convert the RF wave to an IF (Intermediate Frequency) wave. The frequency of the IF wave is determined by:

$$f_{IF} = f_{RF} - f_{LO} \qquad (1)$$

and for this invention is typically a frequency between 1 MHZ and 100 MHz. A suitable IF is chosen to minimize the phase-noise between the IF signals measured at all 4 corners. The IF signals for all receiver elements are "phase coherent", that is, that they share a common phase reference. The IF signals are then entered through an I/Q demodulator **23**. By splitting the IF signals into their I (in-phase) and Q (quadrature-phase) components each receiver channel has a mixture of CDMA coded signals which must be extracted for each transmitting device. These CDMA code modulated signals are sampled with a fast ADC circuit **24** and hence sent to a CDMA processor which determines the I and Q signal component amplitude corresponding to a particular radio transmitting device. The phase and amplitude signals for each active device are determined by:

$$\Phi_i(t) = \tan^{-1}(I_i / Q_i)\,, \qquad (2)$$

$$A_i(t) = \sqrt{I_i^2 + Q_i^2}\,, \qquad (3)$$

where I_i and Q_i are the I/Q signal components for device "i".

The RSS and CPD position locating algorithm of this invention is facilitated by the use of CDMA signals regarding their orthogonality. As shown in Figure 7, two examples of CDMA codes of active radio transmitting device signals, CDMA code A and CDMA code B, are comprised of binary bits in series. These two codes occupy the same spectrum, which is fairly flat across the entire signal bandwidth. Generally speaking, the number of ones and zeros in a CDMA code are approximately equal and evenly distributed in time so that the spectrum is generally flat. If matched-filtering is applied to the sum of CDMA code A and CDMA code B then a correlation peak is output separately for each code match depending which CDMA code is in the filter coefficient array. Note that if CDMA codes A and B are mutually orthogonal then two distinct peaks will appear in the filter or correlator output. The amplitude of these peaks is equal to the square of the signal amplitude received by the receiver elements **3** and therefore the signal processing firmware must perform the square-root operation on each output peak to get the proper I and Q values so that the RSS and CPD can be calculated using equations (2) and (3).

The CDMA detector **7** will use a code-matching filter to determine which code will correlate with the input signal producing a correlation peak output, thereby determining which device **1** is transmitting at that time. The CDMA processor uses a fast multiplexer design to correlate multiple codes using a transposed-form FIR (Finite Impulse Response) architecture as shown in Figure 8. This matched-filter architecture can be implemented in hardware such as high-speed parallel channel DSP, ASIC, or FPGA chips.

Another embodiment of this invention is for each radio receiver element do direct I/Q demodulation without the use of an IF signal. This would simplify the receiver design and not require an intermediate receiver stage but still require a LO **20** to be precisely tuned to the desired radio transmitting device frequency.

Another embodiment of this invention is for each radio receiver element to process an Amplitude Shift-Keying (ASK) modulated signal from each radio transmitting device. For this embodiment the DSSS PN code modulation must be ASK. The type of ASK signal used can be a pulsed ASK signal (i.e. on-off type) or having a varying amplitude. The output of the matched filter will be a correlation peak proportional to the amplitude difference of the ASK modulation.

Another embodiment of this invention is for each radio receiver element to process the varying frequency of a Chirped, frequency hopped, or Frequency Shift-Keyed (FSK) signal from each radio transmitting device. For this embodiment the DSSS PN code modulation must be ASK or FSK based. The frequency of the IF carrier signal is measured at the sum signal using one of several methods such as pulse counting, edge counting, etc. The frequency estimate is then used in the locator algorithm to estimate the location. Changes in carrier frequency provide additional information to aid the location estimate that will

make the radio transmitting device location calculation resistant to errors caused by multi-path effects.

The operation flowchart of the radio transmitting architecture is illustrated in Figure 5. After power up, the system looks for excitation signals from whatever active radio transmitting devices **1** are currently operating with the radio receiver array assembly **3**. These received signals are processed to determine which CDMA codes are present in the input signals. Of the devices that are detected via their CDMA codes, subsequently their XY position is determined. This data is output from the XY locator **7** and data signal extractor **14** to the computer system **8** (or equivalent) that is associated with the receiver array assembly **3**.

In this embodiment, a linear RSS and CPD model is used to calculate the position of each radio transmitting device. It is noted that the free space between devices and the receiver array (see Figures 1A and 1B) comprises an RF impedance that is distributed uniformly in the free space. The signal of each active radio transmitting device **1** is received by all of the elements **3**, and the strength of each received signal is inverse-square related to the distance from the active radio transmitting antenna to the receiver array antennas **3**. Also, the CPD of each radio transmitting device directly related to the change in distance between receiver elements. After matched-filtering the received signals with the CDMA code from each radio transmitting device, the RSS's and CPD's of each device can be determined. Calculations may then be carried out to determine the active radio transmitting position relative to the receiver elements **3**, to be thus to an XY coordinate display unit **9** or XYZ coordinate display unit **10** (Figures 1A and 1B). In this fashion a plurality of active radio transmitting devices **1** may be tracked simultaneously.

The sampled and peak detected signals are measured for the CPD model as the relative phase difference between the signals received at the opposite corners of the receiver array. They are denoted as $\Phi_{1,3}$ and $\Phi_{4,2}$ and that these values are used to approximately determine the X, Y, and Z coordinates by the following formulae:

$$X(t) = R_x(\Phi_{1,3} - \Phi_{4,2}) \ , \qquad (4)$$

$$Y(t) = R_y(\Phi_{1,3} + \Phi_{4,2}) \ , \qquad (5)$$

$$Z(t) = R_z(\Phi_{1,2} + \Phi_{2,3} + \Phi_{3,4} + \Phi_{4,1}) \ , \qquad (6)$$

Where R_x, R_y, and R_z are values that are determined by calibration. In the above equations, the two-dimensional coordinates XY can be determined using a minimum of 4

receivers which is not enough information to determine a Z coordinate. The Z-coordinate is determined by more receiver elements using a minimum of five receiver elements.

In the RSS model the relative amplitude of the signals is measured using equation (5) for each radio transmitting device. The CDMA processor will compute the correlation peaks as signal amplitudes from each of the array elements, which here are labelled here as S_1, S_2, S_3, and S_4. The locator 7 for the RSS model then employs the following algorithm to compute the two or three-dimensional X, Y, and Z position of the radio transmitter to the receiver array **3**:

$$X(t)=((S_1+S_4)-(S_2+S_3))/(S_1+S_2+S_3+S_4)\ , \qquad (7)$$

$$Y(t)=((S_1+S_2)-(S_3+S_4))/(S_1+S_2+S_3+S_4)\ , \qquad (8)$$

$$Z(t)=Z_{fac}(S_1+S_2+S_3+S_4)\ , \qquad (9)$$

Another embodiment to this invention is to identify the presence of a radio transmitting device, if the RSS of that device exceeds a preset threshold, it is recognized to be operating in a radio receiving range, as shown in Figure 6. Thereafter, the determination of the radio transmitting device location is carried out based on RSS's and CPD's obtained from different receiver elements. As is known in the prior art, the RSS is proportional to the distance from each active radio transmitting device to each receiver element, and the maximum threshold range for each active radio transmitting device will vary with the transmitting power of each device and the receiver element sensitivity.

An embodiment to this invention is the adaptive detection and synchronization of CDMA codes with the radio transmitting device in the event that the device CDMA code "chipping" rate differs slightly from chipping rate inside the CDMA detector and processor **13,25**. When a CDMA code is sampled using the ADC **24** of each signal channel (i.e. in the circuit from antenna to ADC) the ADC **24** must over-sample the signal by a factor of 5 to 10 faster than the CDMA chip-rate typically. This ensures that a correlation peak will always form a triangular shape when output from the matched-filter. If there is a slight discrepancy in chipping frequency between the radio transmitting device and CDMA detector and processing unit **13,25** then a correlation triangle will appear distorted but will always form a distinct peak inside the code period. The degree of tolerance discrepancy in chipping frequency improves with a higher over-sampling rate of the ADC to the CDMA code chipping rate.

Another embodiment in this invention is the use of a parallel transposed-form FIR matched-filter as part of the CDMA detector **25**. Figure **8** illustrates the design of this

filter implemented to allow parallel detection of one or a plurality of CDMA codes at high speeds. This filter is designed to share firmware resources and allow CDMA code multiplexing to detect up to "R" CDMA codes in a single code period. For example, if a channel signal is sampled at "N" MHz then this filter can sample up to R different CDMA codes (representing R distinct devices) at a multiplexed rate of "RxN" MHz. This method of designing a filter is flexible depending on the number of maximum radio transmitting devices required.

As another embodiment in this invention a CDMA code can be used to convey a binary communication link between the radio transmitting device and the radio receiver array **2**. As shown in Figure 9, one or a plurality of radio transmitting devices **1** have switches **36** to convey switch event data to the CDMA detector **25**. Binary switch events (e.g. like a right or left mouse click) can be conveyed in the CDMA signal using bit-inversion modulation. The CDMA detector **25** will recognize this modulation as an inversion of the correlation peak thereby allowing the controller to convey the event data as a sign change in the correlator output as often as every code period.

Note that variations of the radiated signal-strength (RSS) caused by signal occlusion and/or multi-path effects can cause amplitude variations to appear in the output signals. Normally this problem is evaded easily by using a normalization calculation of the X and Y coordinate as shown in equations 7,8,9. RSS measurements are affected most so that normalization will restore the relative RSS between signals received at the receiver array elements. Normalization is not required for CPD measurements. However, normalization introduces nonlinear distortion effects in the X-Y position calculation when a radio transmitting device is positioned near one or more of the receiver elements. The reason this occurs is because the sum of all received signals is not a constant amplitude over the radio receiving array area but instead gets larger near the receiver elements.

Essentially there is no difference between 2D and 3D modes in this embodiment because the 2D mode assumes that a fixed Z coordinate in 3D mode had been measured. The wireless transmitter can be a writing stylus and may write on a surface that is transmittable (and not absorptive) of RF electro-magnetic waves. If 3D is chosen then the controller proceeds to calculate a Z coordinate and outputs the data to the computer. If the 3D mode was not chosen the hardware automatically switches to 2D and ignores any 3D coordinate data.

In the case where XY position is calculated to present radio transmitting device locations on a display area **11** by an XY display unit **9** (such as an LED screen seen or video monitor) a method is required to correct for position errors. A software algorithm is required to correct for inaccuracies of misalignment between the receiver array and a display area, to rescale the active receiving area to the display area, or correct offset errors

in the receiver/analog hardware. The algorithm can be executed separately for any radio transmitting device to eliminate accuracy differences between specific controller types. The user is required to move a transmitting device to a minimum of two points on the lower left and upper right of the display area to "rescale" the reported coordinates to these points. Other methods require moving to a displayed grid of points in 3D space to provide more calibration detail.

The following software algorithm can be used to correct inaccuracies due to receiver array and display misalignment, rescale the active receiver area to the display area, or correct offset errors in the receiver analog hardware. The algorithm can be executed separately for 2D mode and 3D to eliminate accuracy differences between the two modes. The user is required to touch the lower left and upper right display area to "rescale" the reported coordinates to these points.

$$X_C = R_X(X - X_L)/(X_U - X_L)\ , \qquad (10)$$

$$Y_C = R_Y(Y - Y_L)/(Y_U - Y_L)\ , \qquad (11)$$

Where:

X_C, Y_C , are the corrected position coordinates

R_X, R_Y , are the resolution limits of the X and Y axes

X_L, Y_L , are the coordinates of the lower calibration point

X_U, Y_U , are the coordinates of the upper calibration point

The software could also enable the system to designate selected 2D or planar transmitters and 3D moving transmitters (like a pen input device or a 3D game input device). This could be accomplished by reporting 2D pen digitization points only in areas designated for pen sensing, and doing the same for 3D transmitter sensing. This feature would be especially useful as a simple means of rejecting pen inputs in an area (potentially the entire screen) designated for handwriting and other stylus-like input, and allow another device like a 3D or even another stylus device to operate independently.

CDMA methodology has been used for wireless communications by military organizations to encode communications information so that the carrier appears to be noise, and thus to be difficult to detect and intercept. CDMA systems operate with high reliability in noisy environments, yet require relatively low power and have relatively high data rates. In this invention, CDMA methodology is used in several unique ways:

1) The system may use only one-way communications from the active radio transmitting device(s) to the screen assembly, rather than two-way communications of prior systems;
2) Once the RSS and CPD are obtained, they are used for both device detection and location tracking. In typical CDMA communications systems, RSS is used only for detection.
3) This invention uses the free space to the receiver array 2 as the signal propagation medium, rather than a broadcast EM field used in wireless CDMA communications. The 3D free-space as a propagation medium enables the RSS and CPD model for the positioning of the devices.
4) The number of active radio transmitting devices may be one, or more than one, depending on the needs of the user.

With reference to Figure 3, the entire analog circuitry for an active radio transmitting device may be embodied in one custom ASIC having approximately 2000 gates or less. Similarly, all digital components of this design may also by encoded as firmware to be downloaded into a microcontroller or FPGA chip. That is, the Power Supply circuit **32**, the RF signal modulator **33**, pulse shaping **38**, and the front-end analog circuits **(18 to 24)** may all be executed in an ASIC. The CDMA code ROM **35a** or LFSR **35b**, and CDMA processing Unit **25**, and XY location calculation 7, and data signal extraction **14**, may be coded into firmware for download into a FPGA, or microcontroller. These possibilities will minimize the device size and enabling a device and controller of small dimensions. The use of a custom ASIC, or readily available microprocessor or FPGA chips also makes the active radio transmitting devices more rugged by reducing component connections, and it minimizes power consumption.

CLAIMS

Other embodiments will occur to those skilled in the art and are within the following claims: We Claim:

1. A radio transmitting system for identifying and locating one or more radio transmitting devices in a radio transmitting area, ~~including:~~ comprising:
   - a signal propagating medium for conducting signals throughout said radio transmitting range;
   - at least one of said radio transmitting devices including means for producing a radio transmitting signal and coupling said signal to said propagating medium, said radio transmitting signal comprising a spread spectrum signal;

- each radio transmitting signal including a unique code identifying the respective device;
- signal receiving means associated with said sensing area and connected to said propagating medium to receive at least one radio transmitting signal from said one or more radio transmitting devices;
- means for decoding said radio transmitting signal to identify at least one of said radio transmitting devices;

2. The radio transmitting system of claim 1, further including means for determining the position of at least one of said radio transmitting devices in said radio transmitting range.

3. The radio transmitting system of claim 1, wherein said one or more radio transmitting devices are active devices.

4. The radio transmitting system of claim 3, further including means for generating an energy field in said propagating medium within said radio transmitting range.

5. The radio transmitting system of claim 4, wherein said energy field includes a spread spectrum signal component.

6. The radio transmitting system of claim 4, wherein each of said radio transmitting devices includes a means to receive a signal through said EM energy field for active radio transmitting device operation.

7. The radio transmitting system of claim 4, wherein said energy field includes an EM field.

8. The radio transmitting system of claim 7, wherein said propagating medium comprises free space in said radio transmitting range.

9. The radio transmitting system of claim 7, wherein said propagating medium comprises an occlusion in said radio transmitting range.

10. The radio transmitting system of claim 5, wherein said spread spectrum signal component is a direct sequence spread spectrum (DSSS) signal.

11. The radio transmitting system of claim 5, wherein said spread spectrum signal component is a frequency hopping spread spectrum (FHSS) signal.

12. The radio transmitting system of claim 5, wherein said spread spectrum signal component modulation is Amplitude Shift Keying (ASK).

13. The radio transmitting system of claim 5, wherein said spread spectrum signal component modulation is Frequency Shift Keying (FSK).

14. The radio transmitting system of claim 1, wherein said unique codes of said one or more radio transmitting devices are orthogonal codes.

15. The radio transmitting system of claim 1, wherein said one or more radio transmitting devices are active devices that generate a radio transmitting signal.

16. The radio transmitting system of claim 15, wherein said radio transmitting signal is an EM signal.

17. The radio transmitting system of claim 16, wherein said propagating medium comprises free space in said radio transmitting range.

18. The radio transmitting system of claim 16, wherein said propagating medium comprises an EM reflecting and conducting layer in said radio transmitting range.

19. The radio transmitting system of claim 15, wherein said signal receiver means includes a plurality of spaced-apart signal receivers, and said means for determining the position of each of said one or more radio transmitting devices includes means for calculating the received signal strengths and phase differences of said radio transmitting signals passing through said propagating medium to said plurality of signal receivers.

20. The radio transmitting system of claim 15, wherein said means for decoding and identifying each of said one or more radio transmitting devices includes matched-filtering means for comparing received radio transmitting signals to stored spread spectrum codes of said one or more radio transmitting devices.

21. The radio transmitting system of claim 1, wherein said at least one radio transmitting device comprises a 2-dimensional mouse controller.

22. The radio transmitting system of claim 1, wherein said at least one radio transmitting device comprises a 3-dimensional mouse controller.

23. The radio transmitting system of claim 1, wherein said at least two radio transmitting device comprises a tilting joystick controller.

24. The radio transmitting system of claim 1, wherein said at least two radio transmitting device comprises a "point-and-shoot" aiming controller.

25. The radio transmitting system of claim 1, wherein said at least three radio transmitting device comprises a 6-DOF controller.

26. The radio transmitting system of claim 1, wherein said at least two radio transmitting device comprises a gesture interface controller.

27. The radio transmitting system of claim 1, wherein a portion of said one or more radio transmitting devices are active devices that generate a radio transmitting signal, and another portion of said one or more radio transmitting devices are semi-active devices. A radio transmitting system for identifying and locating one or more radio transmitting devices in a radio transmitting range, including:

- a signal propagating medium for conducting signals throughout said radio transmitting area;
- at least one of said radio transmitting devices including means for producing a radio transmitting signal and coupling said signal to said propagating medium, said radio transmitting signal comprising a spread spectrum signal;
- each radio transmitting signal including a unique code identifying the respective radio transmitting device;
- signal receiving means associated with said radio transmitting area and connected to said propagating medium to receive at least one radio transmitting signals from said one or more radio transmitting devices;
- means for decoding said radio transmitting signals to identify said one or more radio transmitting devices; and,
- means for determining the position of said one or more radio transmitting devices in said radio transmitting range.

28. The radio transmitting system of claim 28, wherein said at least two radio transmitting device comprises a tilt joystick controller.

29. The radio transmitting system of claim 28, wherein said at least two radio transmitting device comprises an "point-and-shoot"controller.

30. The radio transmitting system of claim 28, wherein said at least one radio transmitting device comprises a 2-dimensional mouse interface controller.

31. The radio transmitting system of claim 28, wherein said at least one radio transmitting device comprises a 3-dimensional mouse interface controller.

32. The radio transmitting system of claim 28, wherein said at least three radio transmitting device comprises a 6-DOF controller.

33. The radio transmitting system of claim 28, wherein said at least two radio transmitting device comprises a gesture interface controller.

34. The radio transmitting system of claim 28, wherein a portion of said one or more radio transmitting devices are active devices that generate a radio transmitting signal, and another portion of said one or more radio transmitting devices are semi-active devices.

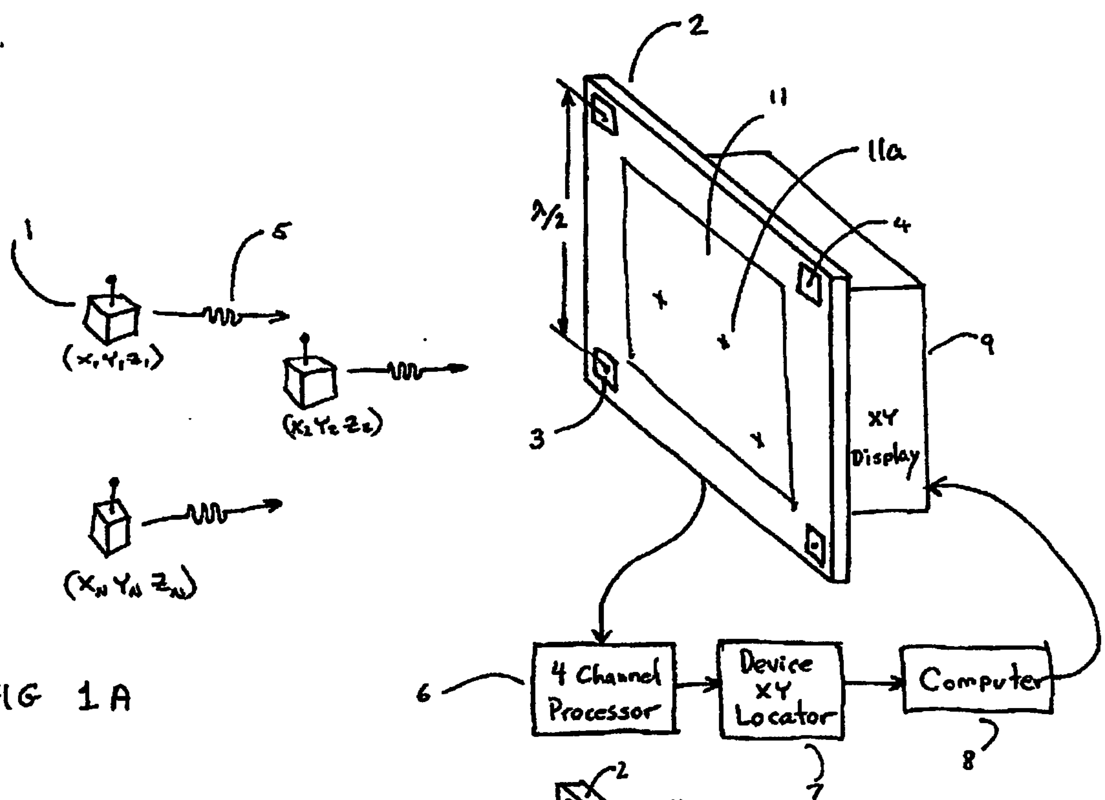

1
5
$(X_1 Y_1 Z_1)$
$(X_2 Y_2 Z_2)$
$(X_N Y_N Z_N)$
2
11
11a
4
$\lambda/2$
3
9
XY Display
4 Channel Processor
Device XY Locator
Computer
6
7
8

FIG 1A

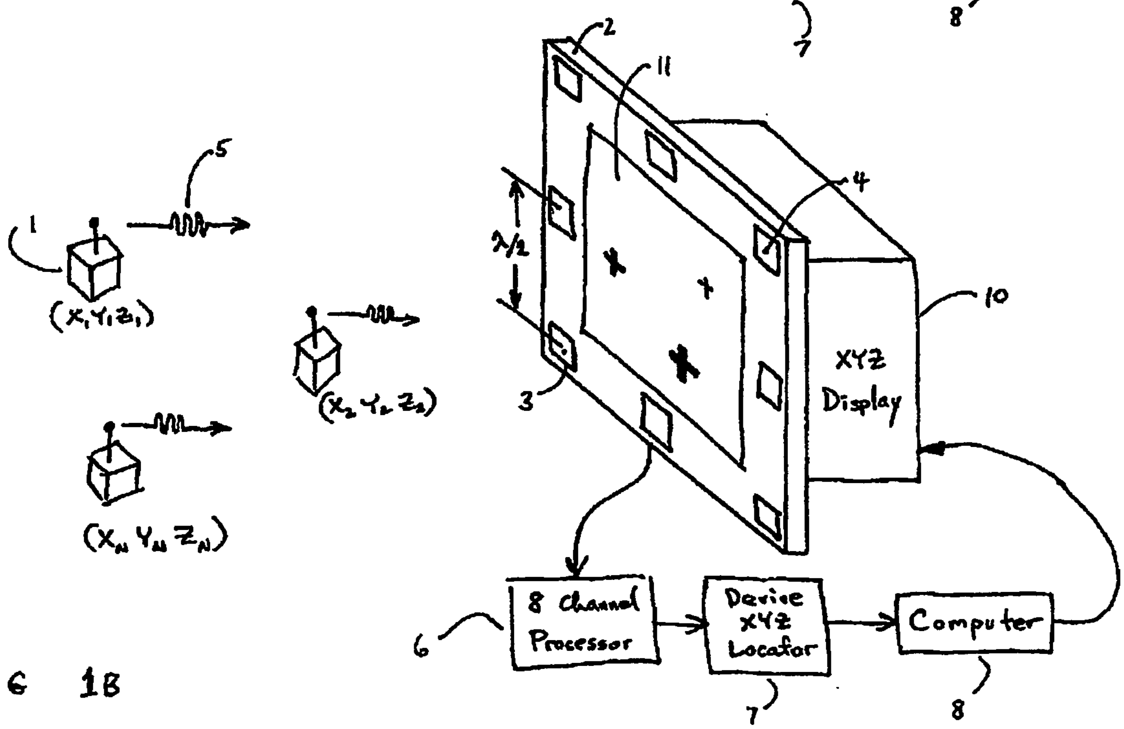

2
11
5
1
4
$\lambda/2$
$(X_1 Y_1 Z_1)$
$(X_2 Y_2 Z_2)$
$(X_N Y_N Z_N)$
3
10
XYZ Display
8 Channel Processor
Device XYZ Locator
Computer
6
7
8

FIG 1B

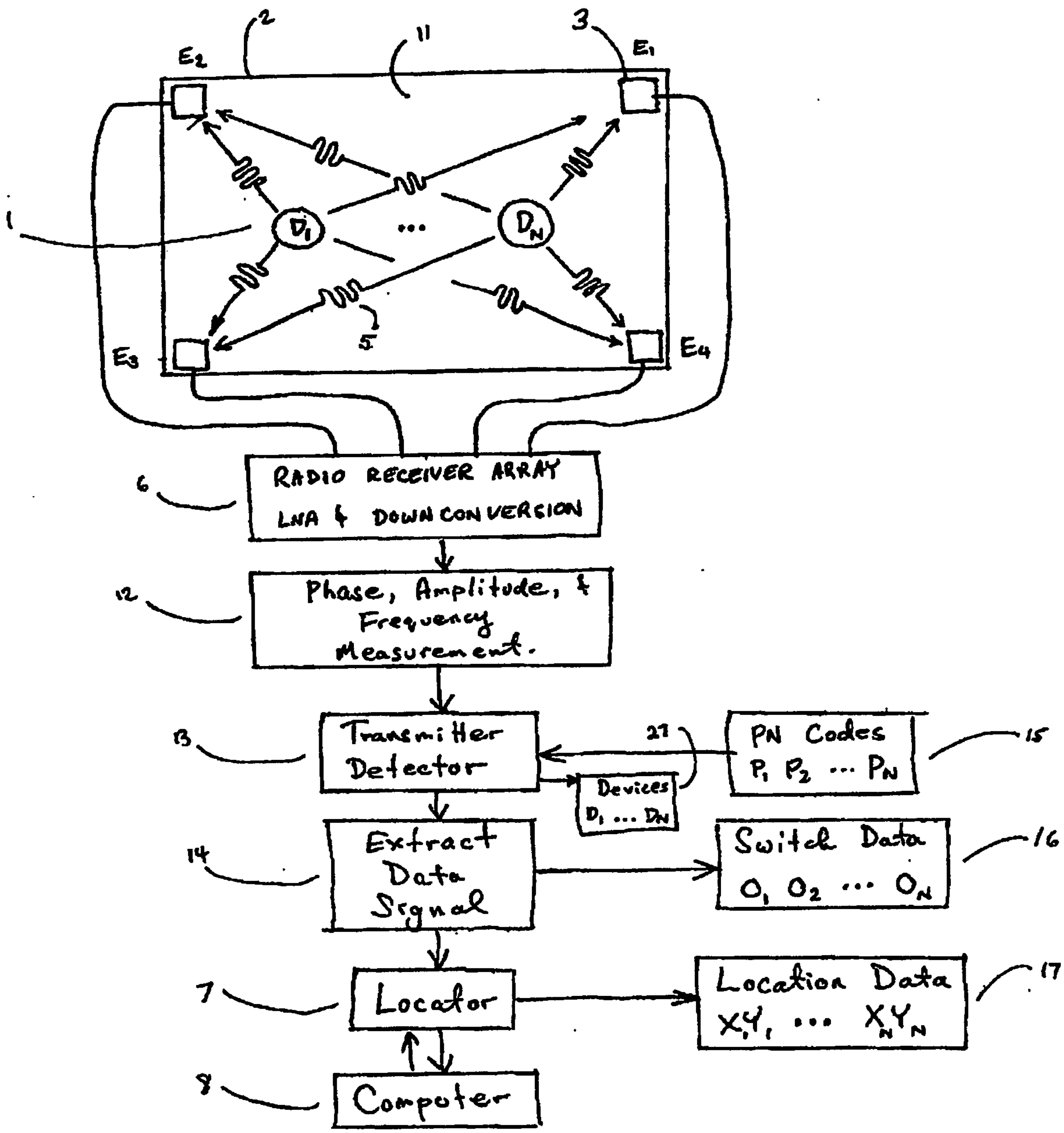


FIG 2 : Multiple Transmitter Detector using DSSS

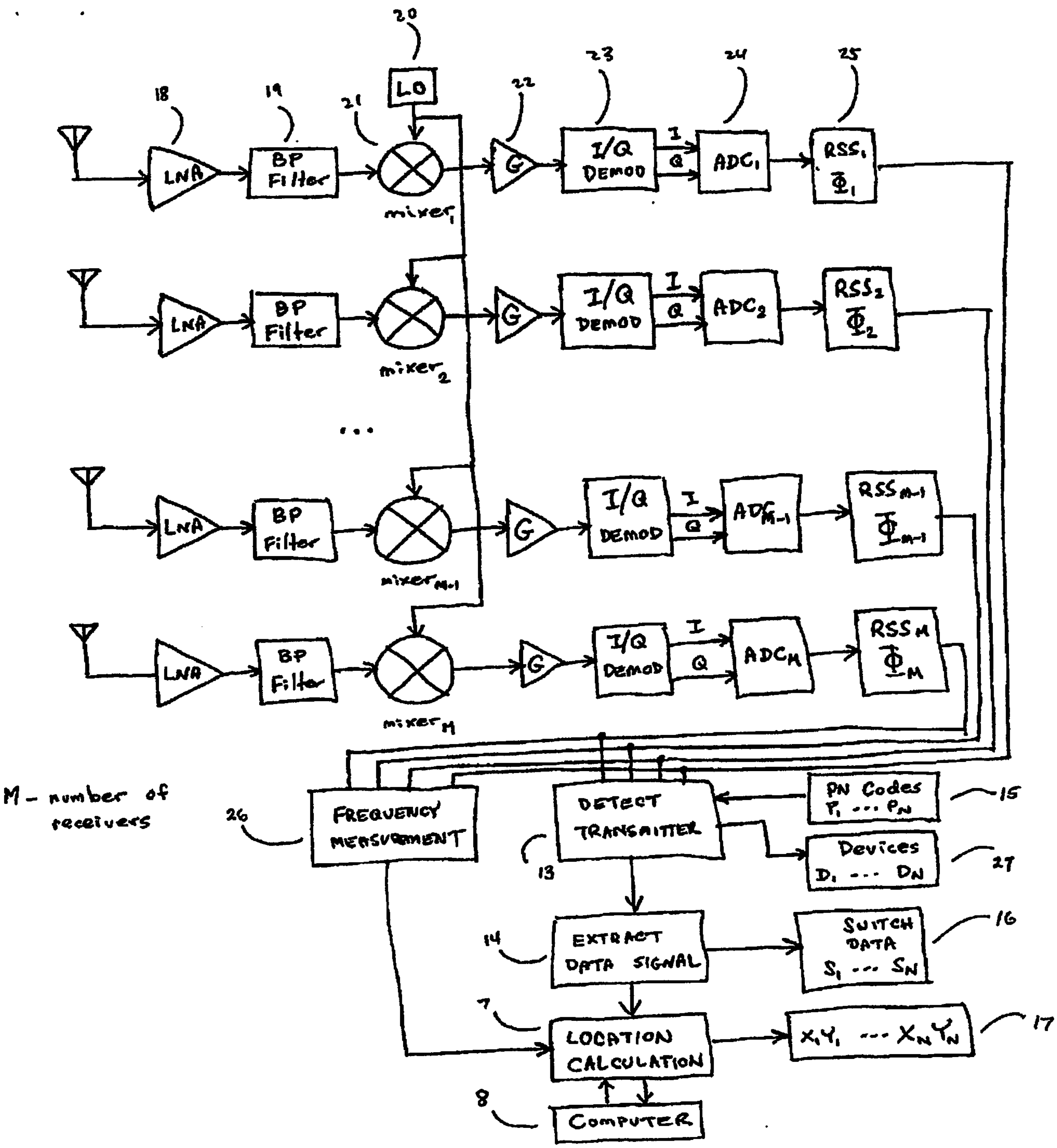


FIG 3 · PROCESSING OF RECEIVER ARRAY SIGNALS.

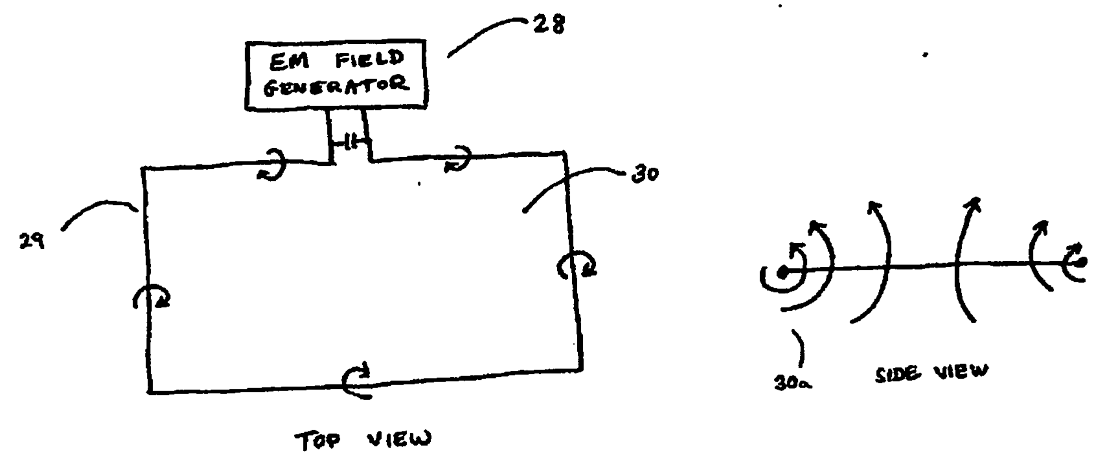


FIG 4A: EM FIELD POWERING CIRCUIT

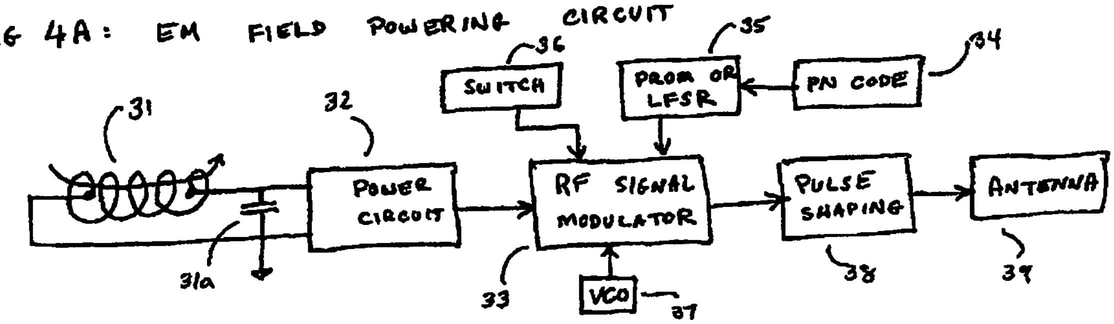


FIG 4B: EM FIELD POWERED SIGNAL TRASMITTING DEVICE

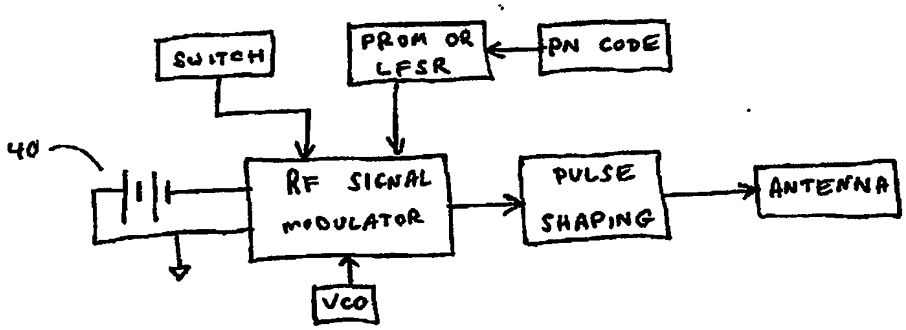


FIG 4C: BATTERY POWERED SIGNAL TRANSMITTING DEVICE

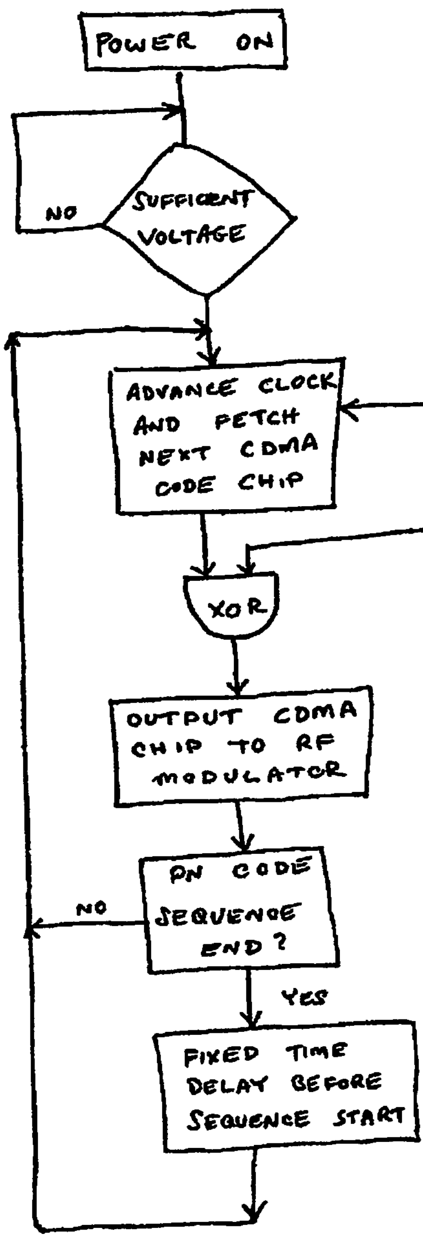


FIG 5: SYSTEM OPERATION FLOWCHART OF ACTIVE RADIO TRANSMITTING DEVICE

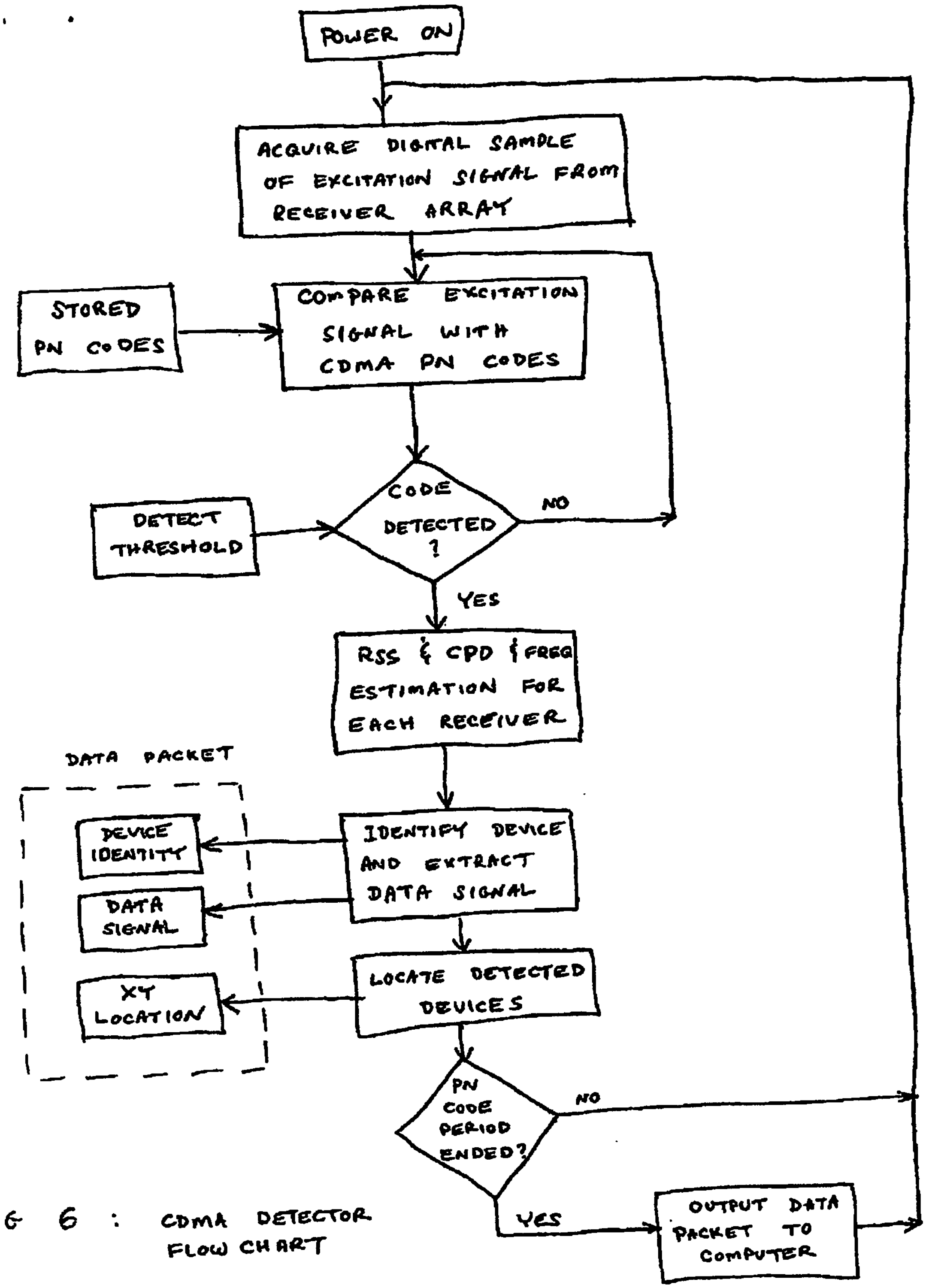


FIG 6 : CDMA DETECTOR FLOW CHART

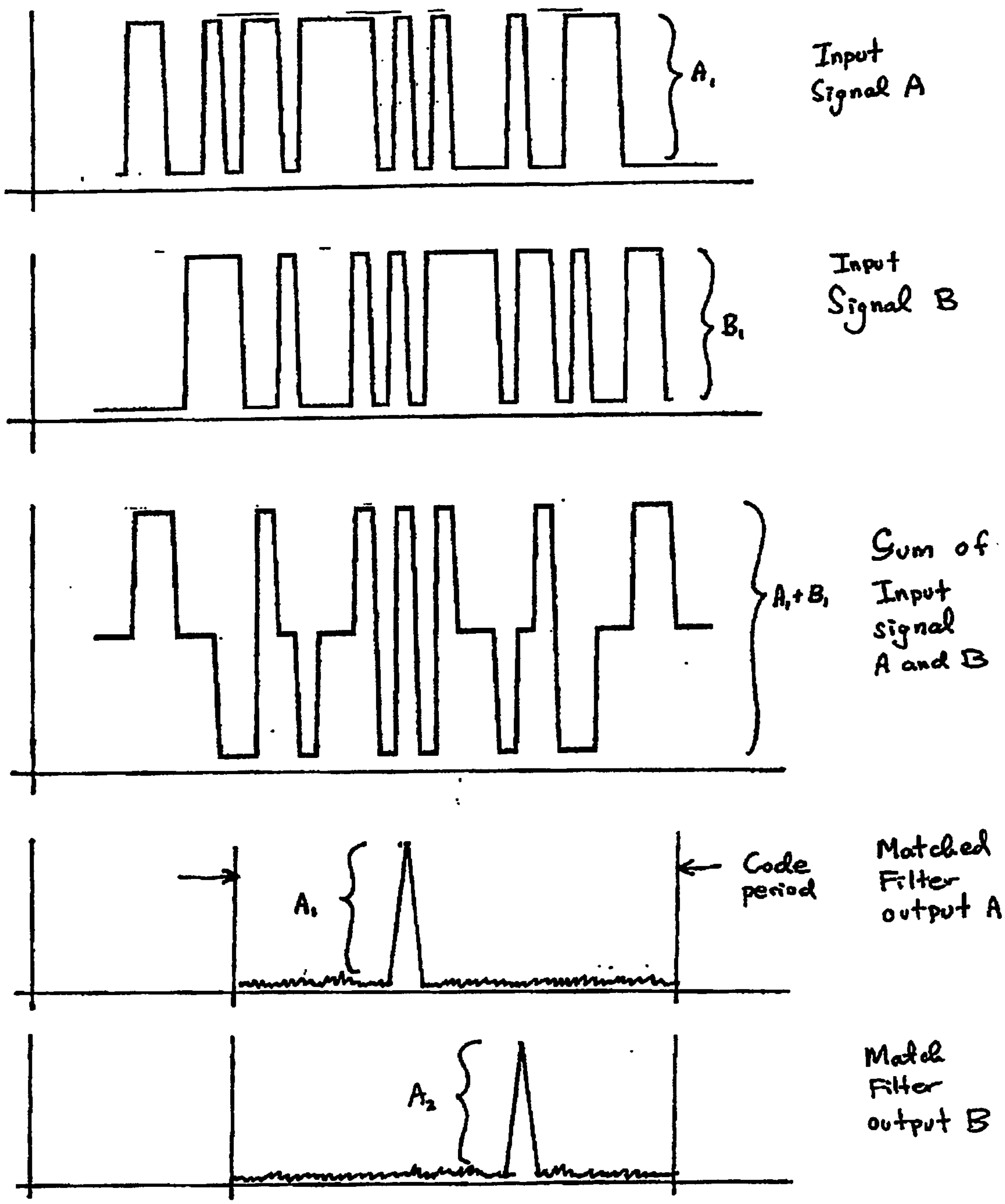
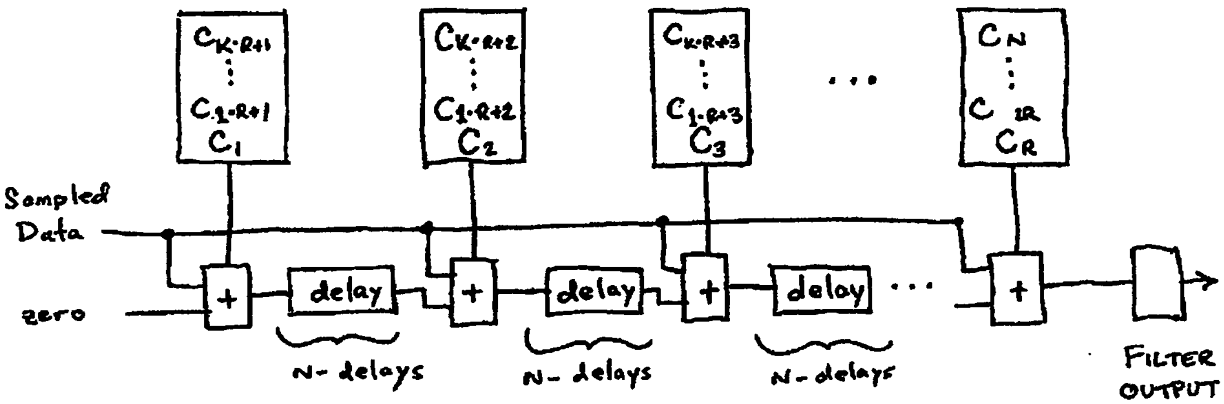


Figure 7 : Multiple channel correlator

Matched-Filter as a transposed-form FIR structure using parallel PN-code channels.



Data Sampled at "S" MHz requires that this filter be clocked at "S×R" MHz

R - number of multiplexed PN codes detected per code period.

N - number of codes maximum (ie max number of devices).

$K = \frac{N}{R}$ number of PN cycles to check all device codes.

FIGURE 8: Parallel channel CDMA processor.

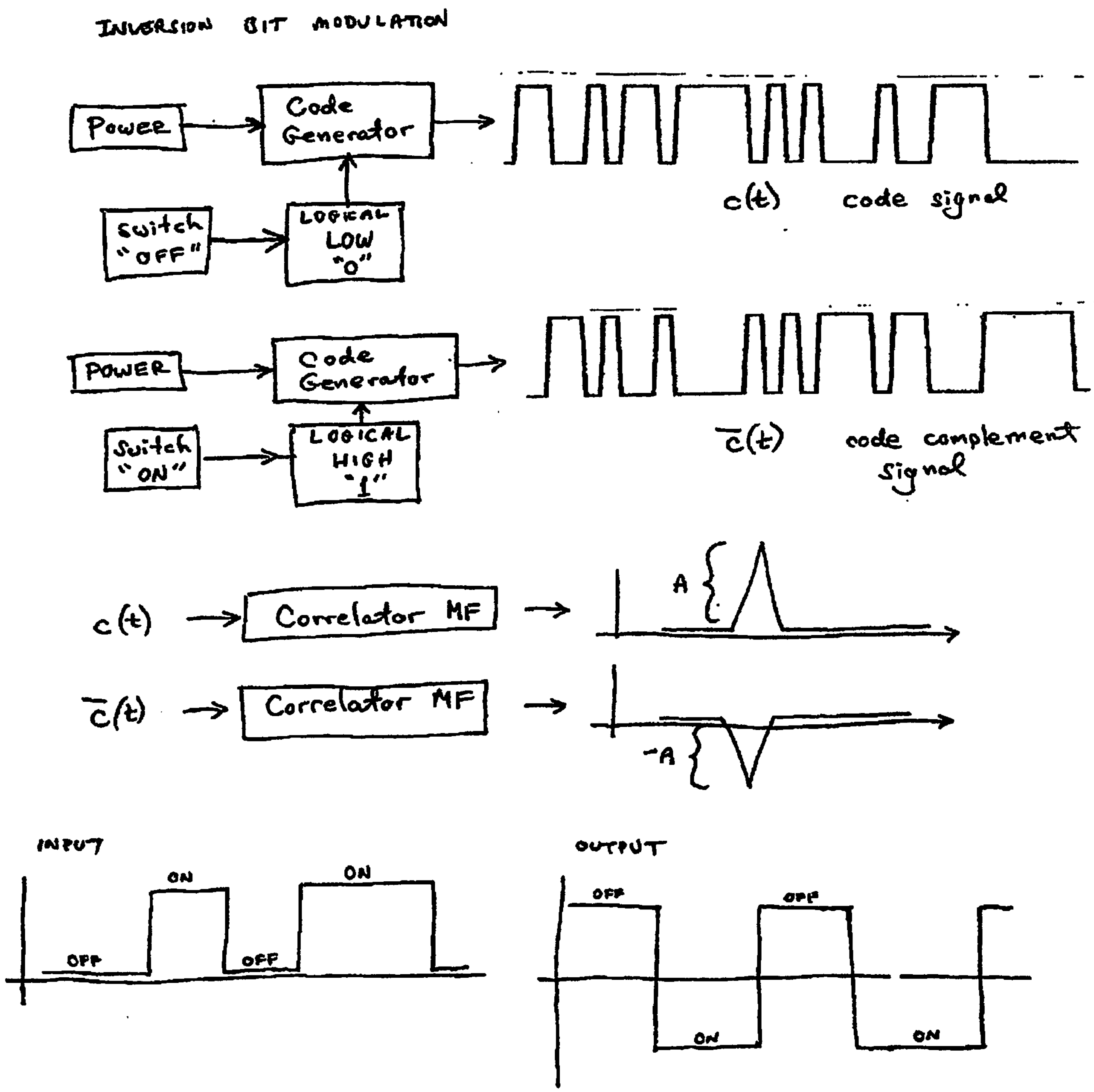


FIGURE 9 : EVENT COMMUNICATION FOR TOUCH INPUT DEVICE.

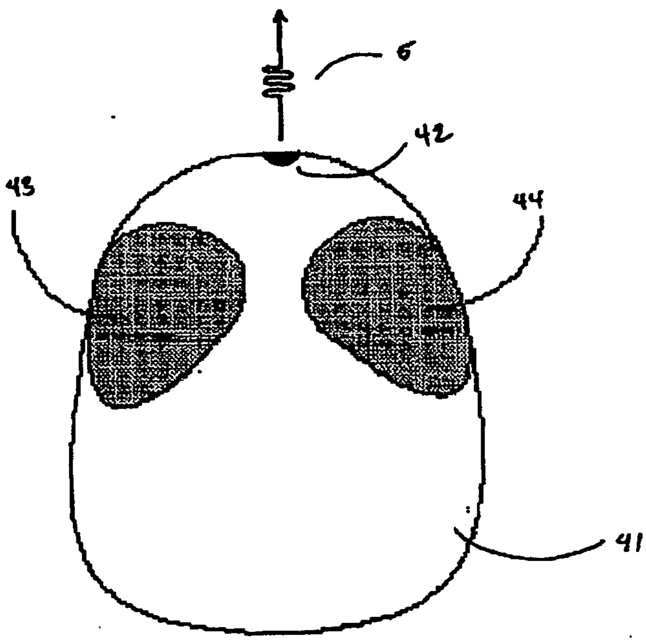


FIG. 10A

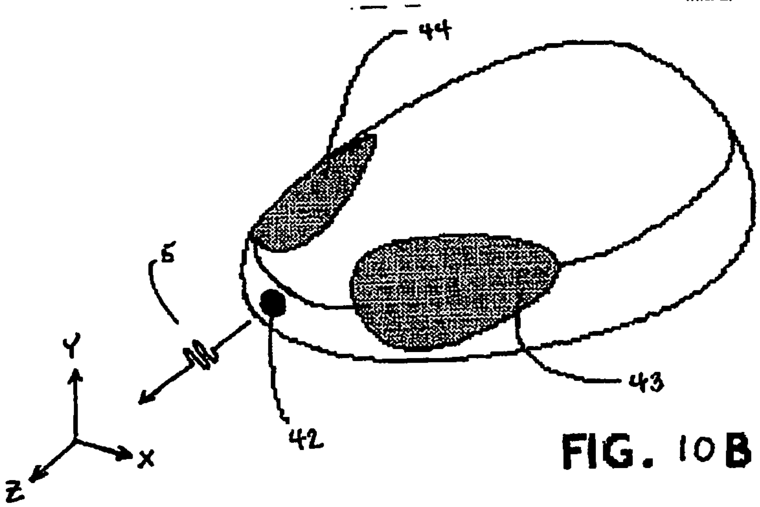


FIG. 10B

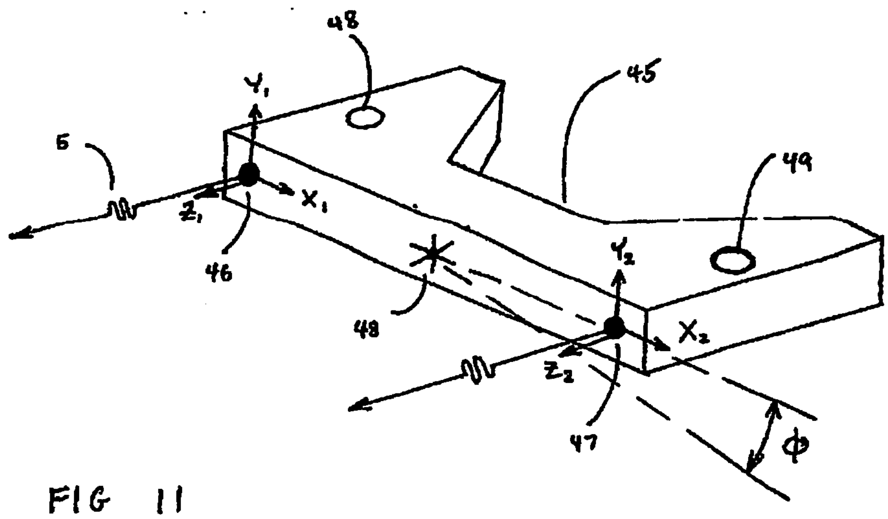

48
Y_1
45
5
49
X_1
Z_1
46
Y_2
48
X_2
Z_2
47
ϕ

FIG 11

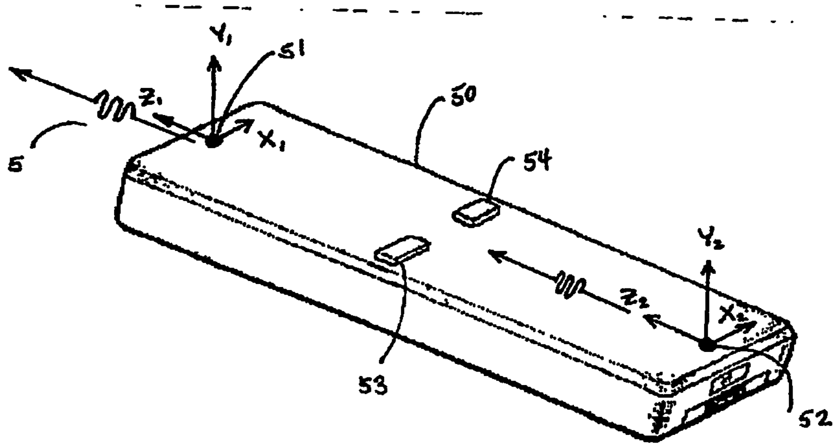

Y_1
51
Z_1
50
X_1
5
54
Y_2
Z_2
X_2
53
52

FIG 12

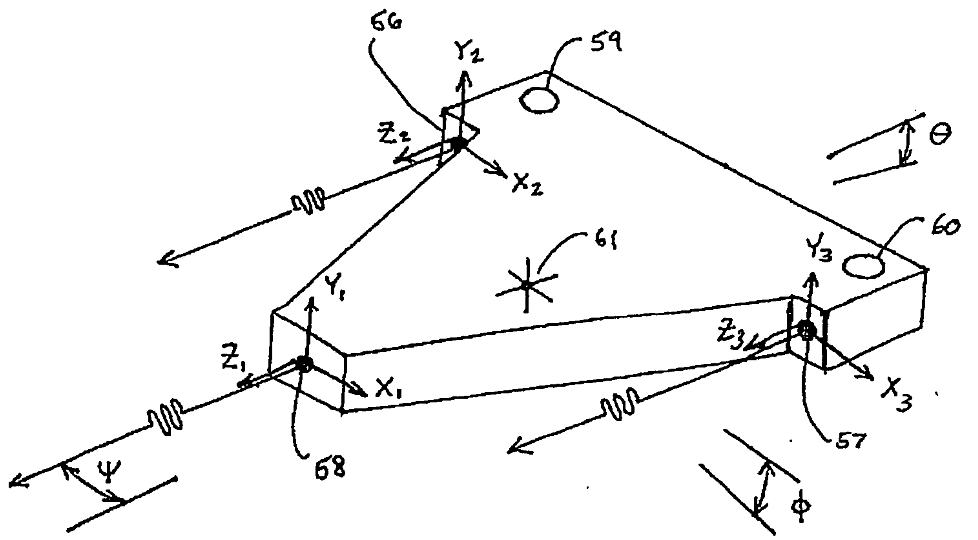


FIG 13

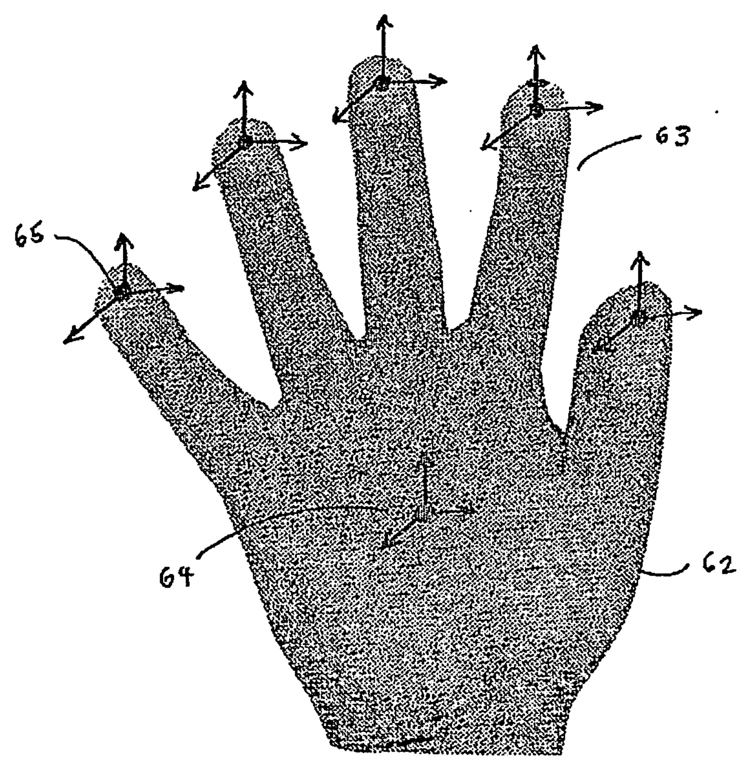


FIG 14